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(54) Displacement sensing

(57) A sensor system senses displacement x of a target surface 13 from a datum plane I. It includes bifurcated fibre-optic 7, comprising light-emitter fibres 5 and light-receiver fibres 6, used with a lens 11 to project white light from lamp 2 onto surface 13 and conduct light reflected from it to photo-detector means whose output is a function of the displacement x. To overcome problems due to different target reflectivities and concerning determining the sense of the displacement x two sensor channels are used, each sensing light at different wavelengths or wavelength bands with substantial spectral separation. Lens 11 images the end surface of the fibres 5 on surface 13 and forms a secondary image on this end surface using the light reflected from the target, the datum plane being the average primary image plane for the two wavelengths. A photodiode P_R senses red light and photodiode P_B senses blue light, beam splitter 19 and filters F_R and F_B being used to separate the red and blue light components of the light from fibres 6. After balancing at 33, the outputs of P_R and P_B are combined in either a differential or a proportional amplifier 35 to produce a system output signal E(x) whose magnitude is dependent on the relative magnitudes of the light fluxes in the two channels, and is hence also a function target displacement from datum plane I.

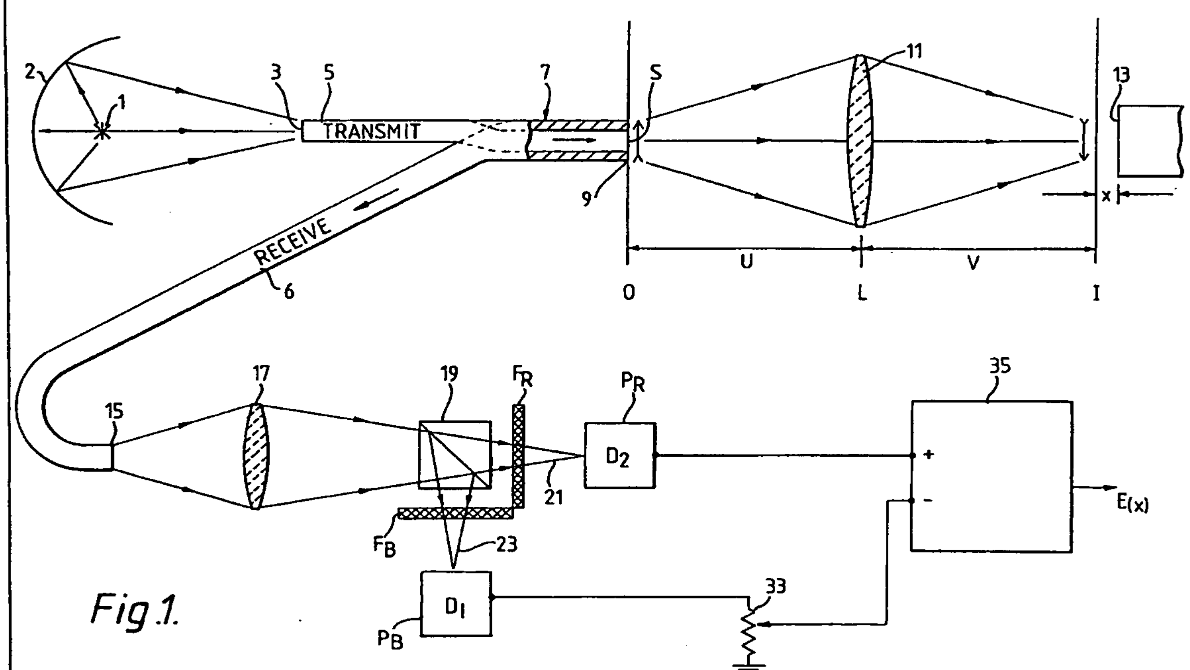

Fig.1.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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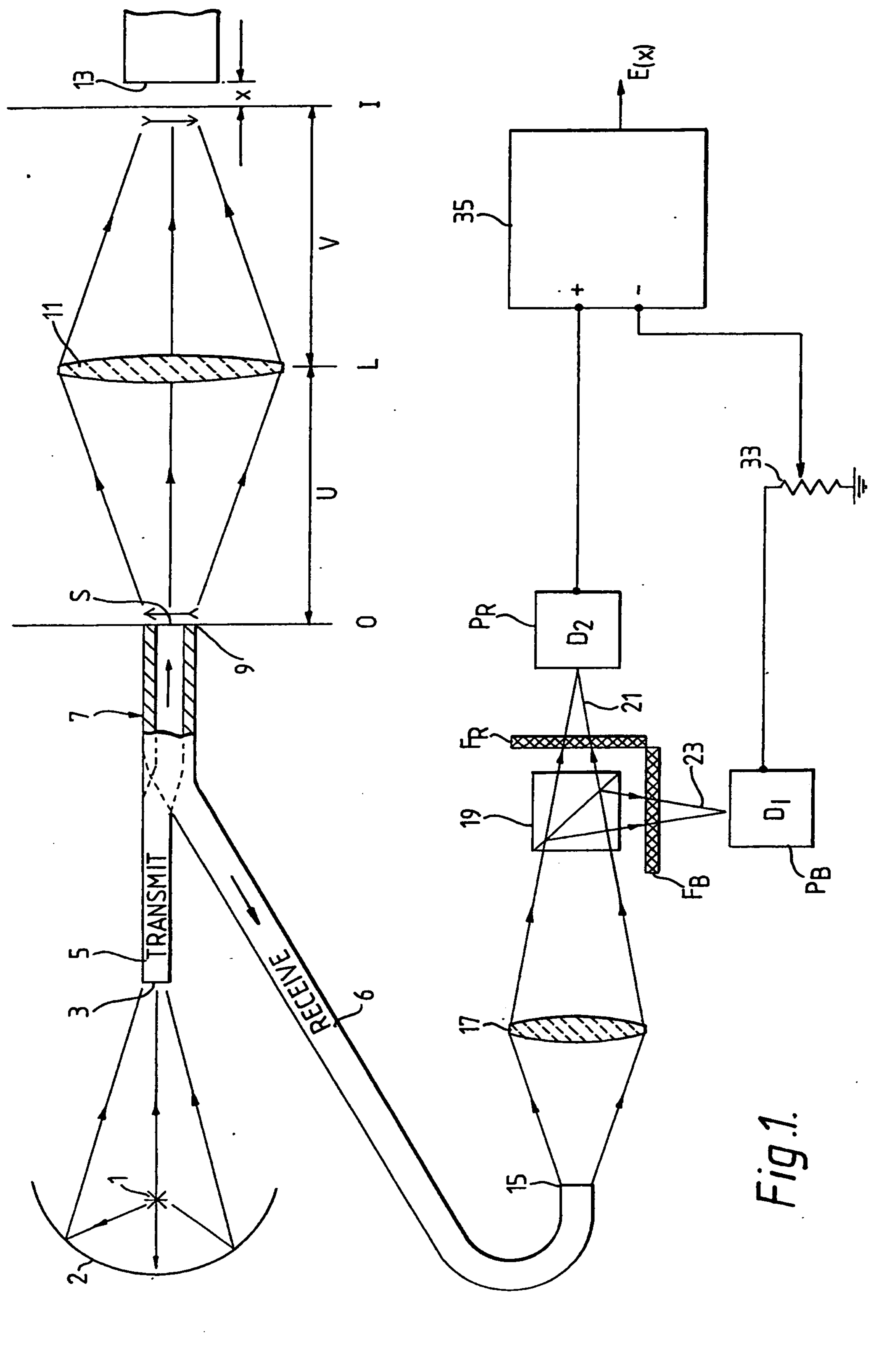
TRANSMIT
RECEIVE
E(x)
35
+
-
33
D_2
P_R
D_1
P_B
F_R
F_B
21
23
19
17
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I
V
L
U
O
S
11
9
7
5
3
6
1
2

Fig.1.

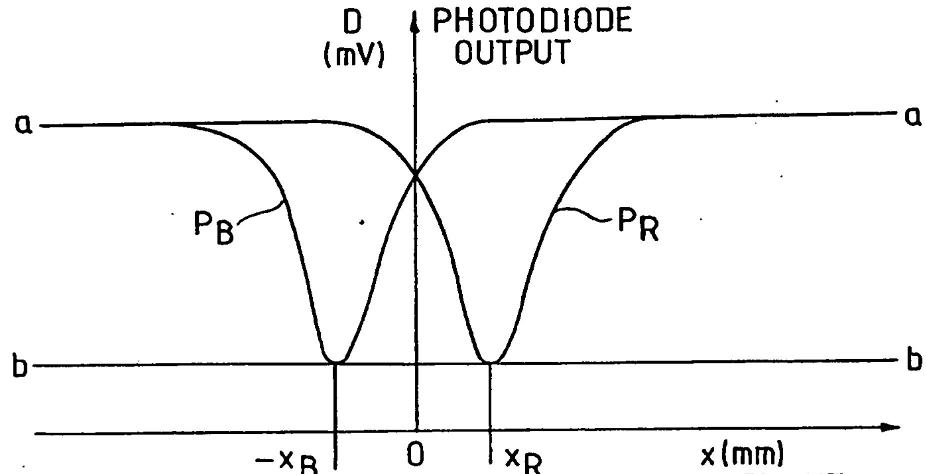
D
(mV)
PHOTODIODE
OUTPUT
a
a
P_B
P_R
b
b
−x_B
0
x_R
x (mm)
DISPLACEMENT

Fig.2.

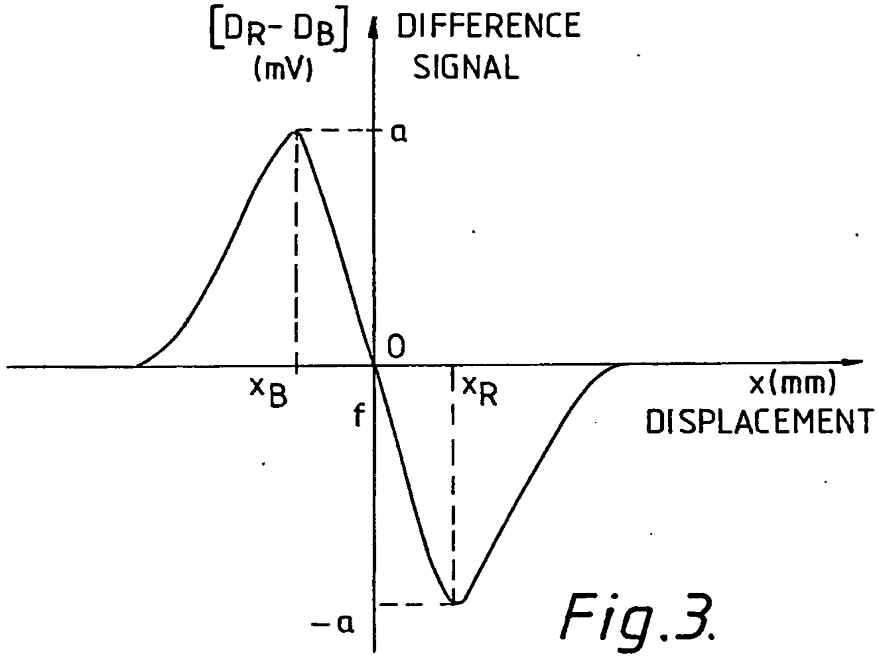
[D_R − D_B]
(mV)
DIFFERENCE
SIGNAL
a
0
x_B
x_R
f
x (mm)
DISPLACEMENT
−a

Fig.3.

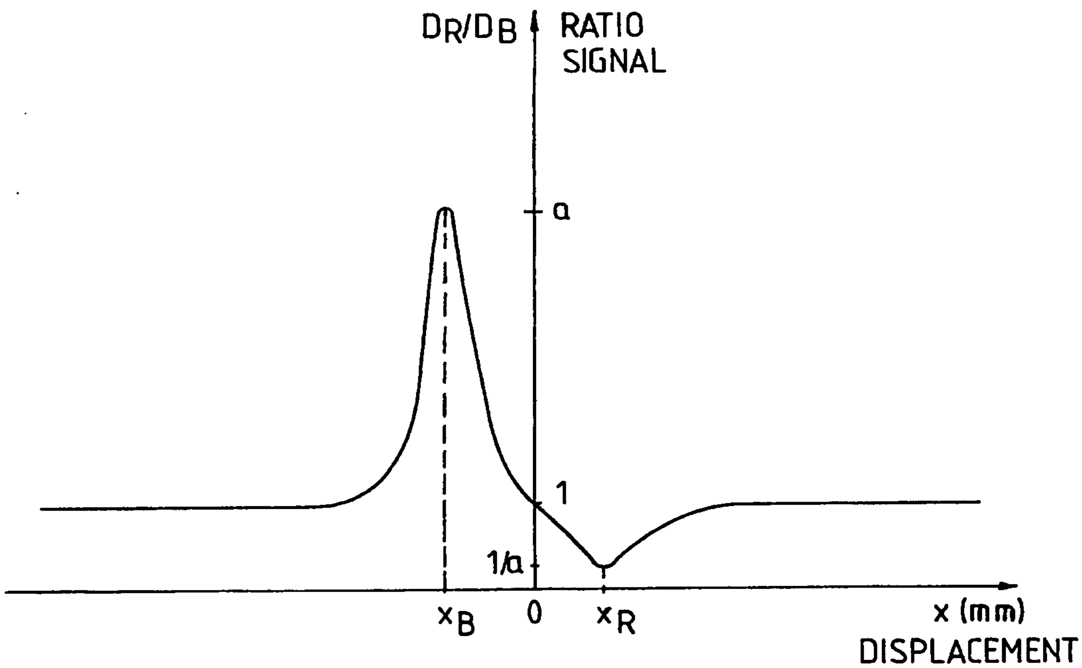

Fig.4.

SPECIFICATION

Chromatic clearance probe
Displacement sensing

The present invention relates to optical apparatus and methods for sensing displacement of a target surface from a datum plane.

Displacement sensors of the fibre-optic sort are already known in which a bifurcated fibre-optic probe, comprising light-emitter fibres and light-receiver fibres, is used in conjunction with a lens system to project light onto the target surface and conduct light reflected from that target surface back to a photodetector (light flux measuring device), the output of the photodetector being a function of the degree of displacement of the target surface from the focal plane of the lens system for the light being projected.

Hitherto, however, such displacement sensors have suffered the disadvantages that in general the output of the photodetector is not readily calibratable to give the sense of the displacement (i.e. whether it is on the lens side of the focal plane or on the distal side), and that the sensors must be recalibrated if the reflectivity of the target surfaces differs by more than a small amount.

The present invention contributes to overcoming these problems by using a displacement sensor system with two sensor channels each sensing light at one wavelength or wavelength band, the two wavelengths or wavelength bands have substantial spectral separation.

According to the present invention, a method of sensing displacement of a target surface from a datum plane comprises:-

generating light including first and second wavelengths or wavelength bands having substantial spectral separation;

emitting said light from a light source which together with light-receiving means occupies a light-emitting and light-receiving surface;

projecting light from the light source onto the target surface by means of a focussing lens to form a primary image of the source on the target surface and projecting light reflected from the target surface back onto said light-emitting and light-receiving surface by means of said focussing lens to form a secondary image of the source on said light-emitting and light-receiving surface, said datum plane being the average focal plane for light from the light source at the first and second wavelengths or wavelength bands; and

producing an output signal whose magnitude is dependant on the relative magnitudes of the light flux received by said light-receiving means at each of the first and second wavelengths of wavelength bands, said output signal being a function of the displacement of the target surface from the datum plane.

Also according to the present invention, a displacement sensor system for sensing displacement of a target surface from a datum plane comprises:-

light generator means for generating light including first and second wavelengths or wavelength bands having substantial spectral separation;

detector means for detecting light emitted by the light generator means;

fibre optic means comprising emitter fibres for conducting light from said light generator means to light-emitting ends of said emitter fibres, and receiver fibres for conducting light from light-receiving ends of said receiver fibres to said detector means, said light-emitting and light-receiving ends forming a light-emitting and receiving end surface of the fibre optic means and said light-emitting ends comprising a light source; and

foscussing lens for projecting light from the light source onto the target surface to form a primary image of the source thereon and for projecting light reflected from the target surface back onto said end surface of the fibre-optic means to form a secondary image of the light source thereon, the datum plane being the average focal plane for light from the light source at the first and second wavelengths or wavelength bands;

wherein the detector means is adapted to produce a system output signal whose magnitude is dependant on the relative magnitudes of the light flux conducted by the receiver fibres at each of the first and second wavelength or wavelength bands; said output signal also being a function of the displacement of the target surface from the datum plane.

In one version of the invention the magnitude of the system output signal is dependant on the different between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands. In another version of the invention the magnitude of the system output signal is dependant on the ratio between the magnitudes of the light flux at each of the first and second wavelengths or wavelengths bands.

The two-channel sensing facility is inherent in the detector means, which can include first and second detectors for producing signals whose magnitudes are a function of the light flux conducted by the receiver fibres at the first and second wavelengths or wavelength bands respectively, and means such as a differential or proportional amplifier for combining the two detector signals as appropriate to produce the system output signal.

Embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Figure 1 is a schematic diagram of a displacement sensor system according to the invention;

Figure 2 is a graph, showing how the output signals of two photo-diodes in Figure 1 vary with the displacement being sensed;

Figure 3 is a graph of the difference between the two photo-diode signals versus the displacement; and

Figure 4 is a graph of the ratio between two photo-diode signals versus the displacement.

The invention utilises the following two known optical properties of a simple focussing lens:

i) Monochromatic light from a source centred on the optical axis on one side of the lens will be focussed onto a target surface in the focal plane on the other side of the lens to form an image of the source, and this image acts as a secondary source so that light reflected back to the lens from the target surface will be refocussed back into the secondary focal plane (i.e. onto the source) as a less brilliant secondary image of the source, this secondary image being the same size as the source. If the source-to-lens distance is kept constant, but the target surface moves towards or away from the lens out of the focal plane, the secondary image at the secondary focal plane will become out of focus and will be of larger size than the source.

ii) Chromatic aberration, i.e. the focal length of a simple lens varies with the wavelength of the light it is focussing.

Referring now to Figure 1, "white" light from a tungsten-halogen lamp 1 is focussed by reflector 2 onto one end 3 of an emitter fibre optic bundle 5, which is joined with a receiver bundle 6 to form a bifurcated combined bundle 7. Bundles 5 and 6 are joined in the combined bundle 7, as indicated partly in section, so that the transmitter bundle 5 forms a central core, the receiver bundle 6 forming a concentric annulus around the core.

At the plane light-emitting and light-receiving end surface 9 of the combined bundle, the end of the emitter bundle 5 forms a circular light source S in a plane O at a fixed distance *u* from the principal plane L of a simple focussing lens 11. The light source S is centred on the optical axis of lens 11, which collects the light from source S and projects it onto the target surface 13 whose displacement x from a datum plane I it is desired to sense. An image of the source S is produced on target surface 13, and this image is of course in focus only when the target surface 13 occupies the focal plane of the lens 11, which is in fact the datum plane I at a focal distance *v* from plane L.

The image on target surface 13 acts as a secondary source for lens 11, and light reflected from the surface 13 is projected back onto the source S by lens 11 to form a secondary image, which will be in focus at plane O and the same size as source S only when the target surface 13 occupies plane I; at all other positions of the target surface 13 closer to or further away from the lens 11, the secondary image at plane O will be out of focus and larger than source S, and hence will extend beyond the boundary of the source S to overlap at least part of the surrounding annulus of the receiver fibre-optic bundle, the amount of overlap being indicative of the magnitude of the displacement.

Although in the above paragraph, the primary and secondary images are said to be "in focus" when target surface 13 is at plane I, there will in fact be some blurring due to chromatic aberration in lens 11, because "white" light is being utilised, and hence the secondary image at plane O will actually be slightly bigger than the source S, so that it overlaps receiver bundle 6 to a small extent.

Any light received at plane O by the fibres in receiver bundle 6 is conducted to the other end 15 of the bundle where it is emitted. It is then collected by a further lens 17, which projects the light onto a cube beam splitter 19 so as to produce two light beams 21, 23. The lens 17 brings the light beams 21, 23 to a focus on photodiodes P_R, P_B respectively, but each light beam is first passed through a respective optical filter F_R or F_B, which each pass only light of a chosen wavelength or band of wavelengths; filter F_R passes light at a wavelength band at the red end of the spectrum, and filter F_B passes light at a blue wavelength band. The system is thus provided with two sensor channels having a wide spectral separation.

As alternatives to the use of the beam splitter and filters as described above, other devices such as a prism or a dichroic filter could be used to separate light at the two wavelength bands of interest from the light conducted by the receiver bundle 6 and pass each wavelength to the appropriate one of the photodiodes.

From the above explanation, it will be evident that photodiode P_R is the "red" sensor channel, being affected by the red component of the secondary image, and photodiode P_B is the "blue" sensor channel, being affected by the blue component. When the red image component is exactly in focus at plane O, it will also be exactly coextensive with the source S. Therefore the receiver bundle 6 will not pick up any red light and the output of photodiode P_R will be at a base level. However, the output of photodiode P_B will be above base level because receiver bundle 6 will be picking up some blue light from the unfocussed blue image component. Similarly, when the blue image component is exactly focussed at plane O, the red image component will be unfocussed, and the outputs of photodiodes P_R and P_B will be above base level and at base level respectively.

Figure 2 shows idealised photodiode response curves, in which the magnitude of the photodiode output signals D in millivolts are plotted against the displacement, x, of the surface 13 from plane I, which is actually the plane of average focus between the red and blue image components, the focal plane for blue light being closer to lens 11 than the focal plane for red light if lens 11 is made of optical crown glass. The curves are labelled for their respective diodes P_R and P_B as appropriate. The base level "b" in the Figure corresponds to background light intensity, scattered light and crosstalk within the optical fibre bundle, and the level "a" represents the maximum actual signal levels. At displacement $-x_B$, the output of photodiode P_B is at the minimum, signifying that the blue image component is in focus, but at this stage the red image component is out of focus, and the photodiode P_R is still giving a maximum or near-maximum output. At displacement

$+x_R$, the output of photodiode P_R is at the minimum, signifying that the red image component is in focus, but the blue image component is now out of focus, giving photodiode P_B a maximum or near-maximum output.

The maximum and minimum output signal levels from photodiodes P_R and P_B will in fact be somewhat different from each other due to various factors such as the differing effect of blue and red light on the photodiodes and the different transmission characteristics of the receiving and transmitting fibre optics. However, by suitable choice of photodiodes whose sensitivities are optimised for their task, and balancing of the output signals of the photodiodes by adjustment of potential divider 33 (Figure 1), the response curves of Figure 2 are obtained.

Ir will be seen from Figure 2 that the photodiode sensitivities, etc., are adjusted so that at $x = 0$, i.e. when the surface 13 is in plane I, the values of D for both photodiodes P_R and P_B are the same, i.e. $D_R = D_B$ so that their difference is zero and their ratio is unity. Hence, the outputs of the photodiodes can be combined in these two ways to produce a combined signal whose value is indicative of both the sense and magnitude of the displacement x. In Figure 1, the equalised signals from photodiodes P_R and P_B are fed to a differential or proportional amplifier 35 and the magnitude of the output E(x) from the amplifier is taken as a measure of displacement x, i.e. the magnitude of the system output signal E(x) is dependent on the relative magnitudes of the light flux sensed by the two sensor channels.

Figure 3 is a plot of the difference between the photodiode output signals in Figure 2 (i.e. $D_R - D_B$), against displacement, x. It will be seen that the difference signal is quite linear with respect to displacement over an appreciable proportion of the curve between the "red" and "blue" focal distances x_R and x_B respectively. The output of the amplifier 35 can thus be fed to a meter or digital readout calibrated directly in units of displacement. When an actual system was tested in the laboratory, it was found that for a blue focal plane at $x = -6$ mm and a red focal plane at $x = +6$ mm, the difference signal was substantially linear within ± 5 mm of the average focal plane at $x = 0$, and the sensitivity was approximately 20 m V per mm. These results were obtained using a 25 mm diameter, 50 mm focal Ealing crown glass lens. Filter F_R was an 830 mm long pass red filter and filter F_B was a heat absorbing filter. This illustrates that the invention provides a simple non-contact way of measuring small variations in distance accurately.

A disadvantage in taking the difference of the photodiode outputs as an indication of displacement is consequential on the widely varying reflectivities of different materials and surface finishes. If a number of different objects are being observed in succession, or if the surface condition of an object being observed varies appreciably with time, the amount of light being received by the receiver fibres will also vary, and this will affect the magnitude of the difference signal and hence the apparent magnitude of the displacement. This can be overcome by re-calibrating the output E(x) from the differential amplifier 35, but this is time-consuming and in fact impossible if it is desired to observe objects with differing reflectivities in rapid succession.

The problem of varying reflectivity can be overcome for most surfaces by combining the photodiode outputs to produce a ratio signal as mentioned above. This can be shown by considering the variables on which the photodiode output signals depend. The photodiode output signal D at, say, displacement x_1 and wavelength λ_1, is given empirically by

$$D(x_1,\lambda_1) = f(\lambda_1)\cdot R(\lambda_1)\cdot S(\lambda_1)\cdot G(x_1,\lambda_1)$$

In the above equation, $f(\lambda_1)$ is a spectral distribution term, dependent on the well known Planck spectral distribution law, and is altered by variations in the filament temperature of lamp 1. It is found that variations of $f(\lambda_1)$ are not serious for a tungsten-hologen lamp, assuming a filament temperature fluctuation of ± 50°K. $S(\lambda_1)$ is an effective diode sensitivity which allows for transmission losses in the system. It is common to all surfaces and lamp sources and is therefore allowed for in the initial calibration of the system. $G(x_1,\lambda_1)$ is the geometric factor for the system, representing the fact that the amount of light received by the photodiode varies with the state of focus of the secondary image which in turn depends upon displacement of the surface and the wavelength of the light. $R(\lambda_1)$ represents the reflectance of the surface, which varies widely from surface to surface as mentioned above. However, it is found that for the two wavelengths being considered, the ratio of the reflectances at each wavelength for any pair of diffuse reflecting surfaces will have the same value. (Retro-reflective and mirror surfaces are a special case and require separate calibration). To a good approximation, therefore, it is possible to write

$$\frac{D(x_1,\lambda_R)}{D(x_1,\lambda_B)} = \frac{G(x_1,\lambda_R)}{G(x_1,\lambda_B)} = E(x),$$

where E(x) is the system output signal from the amplifier 35 (which in this case is a proportional amplifier) which can be calibrated directly in terms of displacement. The photodiode sensitivities are adjusted to normalise E(x) to 1 when $x = 0$, that is when the target surface is at average focus.

Figure 4 is a plot of the ratio D_R/D_B between the photodiode output signals, against displacement, x. It is simple to tell whether the observed surface is nearer to or further away from the lens 11 than plane I, depending on whether the output signal $D_R/D_B = E(x)$ is respectively greater or lesser than unity. The graph is not so linear near $x = 0$ as for Figure 3.

In order to produce a more accurate result, the system could also incorporate monitoring of the "red" and "blue" spectral radiances of the light source, these being used to apply a correction to the system output for errors arising from the ratio $f(\lambda_R) / f(\lambda_B)$. It would also be possible to replace the tungsten-halogen light generator by a mercury discharge lamp or a red and green light-emitting diode, or indeed sufficiently stable light generator emitting light at two frequencies or frequency bands having sufficient spectral separation to enable satisfactorily different focal lengths to be attained.

The range over which displacement x can be satisfactorily sensed can easily be adjusted within the optical limits of the system to suit particular requirements. This can be shown by considering the well known convex lens equation

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

(where u and v have the meanings assigned them in connection with Figure 1 and f is the focal length of the lens for light of a particular wavelength coming from infinity). From this it is apparent that an alteration in distance u will produce an alteration in distance v, the alteration in v for red light being different from the alteration in v for blue light. In fact, as u is reduced the difference between the focal lengths for red and blue light will increase, thus enabling the working range of the system to be adjusted as required. However, once the system has been calibrated, the source-to-lens distance u should preferably be kept constant to avoid the need for recalibration.

In the above description, only one configuration for the combined fibre optic bundle 7 is mentioned, but other configurations are possible, as mentioned below.

A major factor in the sensitivity and measurement range of the device is the distribution of optical fibres at the transmitting/receiving end 9 of the combined bundle. A greater displacement sensitivity could be obtained by using a random distribution of transmitter and receiver fibres at the end 9, but the range of displacements which could be sensed would be reduced as compared with the core/annulus arrangement in Figure 1.

In another arrangement, the circular end of the combined bundle could comprise two semi-circles, the bundle being divided along a diameter, one half consisting of transmitter fibres, the other half consisting of receiver fibres. This is a cheaper arrangement than a core/annulus arrangement, but produces smaller photodiode signals.

Yet another arrangement is a core/annulus arrangement in which the receiver fibres comprise the core and the transmitter fibres comprise the surrounding annulus. This also produces smaller photodiode signals.

Although the two-channel displacement sensor system has been described thus far merely as a means of measuring displacement, it could conveniently be used as an element in a servo-controlled system in which the system output signal, E(x), is used as a feedback to the servo mechanism to control the position of the target surface. For instance, if it is desired to maintain an optimum clearance between a static radially outer component, such as a known variable diameter segmented turbine casing, and a rotating radially inner component, such as a turbine blade, the displacement sensor system can be mounted to look through a small aperture in the turbine casing at the radially outer tip of the turbine blade as it passes the aperture, the tip of the blade being the target surface and the sensor optics being arranged so that the plane of average focus coincides with the radial position of the blade tip for optimum clearance. The signal E(x) at optimum clearance will be either zero or unity according to whether the difference or ratio modes of operation are used (Figure 3 or Figure 4 respectively), and the servo acts to restore E(x) to these values if the clearance becomes greater or less than the optimum by actuating e.g. a motor driven cam mechanism as known to decrease or increase the effective diameter of the segmented casing as necessary.

CLAIMS

1. A displacement sensor system for sensing displacement of a target surface from a datum plane, comprising:-

light generator means generating light including first and second wavelengths or wavelength bands having substantial spectral separation;

detector means for detecting light emitted by the light generator means;

fibre optic means comprising emitter fibres for conducting light from said light generator means to light-emitting ends of said emitter fibres and receiver fibres for conducting light from light-receiving ends of said receiver fibres to said detector means, said light-emitting and light-receiving ends forming a light emitting and receiving end surface of the fibre optic means and said light-emitting ends comprising a light source; and

a focussing lens for protecting light from the light source onto the target surface to form a primary image of the course thereon and for projecting light reflected from the target surface back onto said end surface of the fibre-optic means to form a secondary image of the source thereon, the datum plane being the average focal plane for light from the light source at the first and second wavelengths or wavelength bands;

wherein the detector means is adapted to produce a system output signal whose magnitude is dependent on the relative magnitudes of the light flux conducted by the receiver fibres at each of the first and second wavelengths or wavelength bands, said output signal also being a function of the displacement of the target surface from the datum plane.

2. A displacement sensor according to claim 1 in which the detector means is adapted to produce an output signal whose magnitude is dependent on the difference between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands.

3. A displacement sensor according to claim 1 in which the detector means is adapted to produce an output signal whose magnitude is dependant on the ratio between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands.

4. A displacement sensor according to any one of claims 1 to 3 in which the detector means includes first and second detectors for producing signals whose magnitudes are a function of the light flux conducted by the receiver fibres at the first and second wavelengths or wavelength bands respectively, and means combining said signals to produce the output signal.

5. A displacement sensor according to claim 4 in which the detector means includes means for separating light at the first and second wavelengths or wavelength bands from the light conducted by the receiver fibres and passing the light at the first and second wavelengths or wavelength bands to the first and second detectors respectively.

6. A displacement sensor according to claim 4 or claim 5 as dependant from claim 2 only in which the means combining the signals produced by the first and second detectors comprises a differential amplifier.

7. A displacement sensor according to claim 4 or claim 5 as dependant from claim 3 only in which the means combining the signals produced by the first and second detectors comprises a proportional amplifier.

8. A displacement sensor according to any one of claims 4 to 7 in which the first and second detectors comprise photodiodes.

9. A method of sensing displacement of a target surface from a datum plane, comprising:-

generating light including first and second wavelengths or wavelength bands having substantial spectral separation;

emitting said light from a light source which together with light-receiving means occupies a light-emitting and light-receiving surface;

projecting light from the light source onto the target surface by means of a focussing lens to form a primary image of the source on the target surface and projecting light reflected from the target surface back onto said light-emitting and light-receiving surface by means of said focussing lens to form a secondary image of the source on said light-emitting and light-receiving surface; said datum place being the average focal plane for light from the light source at the first and second frequencies of frequency bands; and

producing an output signal whose magnitude is dependent on the relative magnitudes of the light flux received by said light-receiving means at each of the first and second wavelengths or wavelength bands, said output signals being a function of the displacement of the target surface from the datum plane.

10. A method according to claim 9 in which the magnitude of the output signal is dependent on the difference between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands respectively.

11. A method according to claim 9 in which the magnitude of the output signal is dependent on the ratio between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands respectively.

12. A displacement sensor substantially as described in this specification with reference to and as illustrated by Figure 1 of the accompanying drawings.

13. A method of sensing displacement substantially as described in this specification with reference to Figure 1 of the accompanying drawings.

New claims or amendments to claims filed on 21st May 1981
Superseded claims All
New or amended claims:- 1 to 15

1. A displacement sensor system for sensing displacement of a target surface from a datum plane, comprising:-

light generator means for generating light including first and second wavelengths or wavelength bands having substantial spectral separation;

fibre-optic means comprising light-emitter fibres and light-receiver fibres, said fibre-optic means having an end surface comprising a central light-emitter surface composed of said light-emitter fibres, said light-emitter surface acting as a light-source, and a peripheral light-receiver surface composed of said light-receiver fibres;

a focussing lens for projecting light from the light source onto the target surface to form a primary image of the light source thereon and for projecting light reflected from the target surface back onto said end surface of the fibre-optic means to form a secondary image of the source thereon, the datum plane being the average focal plane for light from the light source at the first and second wavelength or wavelength bands; and

detector means coupled to the light-receiver fibres for detecting light conducted thereby, the detector means being adapted to produce a system output signal whose value is dependent on the relative magnitudes of the light flux conducted by the receiver fibres at each of the first and second wavelengths or wavelength bands and hence also on the sense and magnitude of the displacement of the target surface from the datum plane.

2. A displacement sensor system according to claim 1 in which the detector means is adapted to produce a system output signal whose value is dependent on the difference between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands.

3. A displacement sensor system according to claim 1 in which the detector means is adapted to produce a system output signal whose value is dependent on the ratio between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands.

4. A displacement sensor system according to any one of claims 1 to 3 in which the detector means includes first and second detectors for producing signals whose magnitudes are a function of the light flux conducted by the receiver fibres at the first and second wavelengths or wavelength bands respectively, and means combining said signals to produce the output signal.

5. A displacement sensor system according to claim 4 in which the detector means includes means for separating light at the first and second wavelengths or wavelength bands from the light conducted by the receiver fibres and passing the light at the first and second wavelengths or wavelength bands to the first and second detectors respectively.

6. A displacement sensor system according to claim 4 or claim 5 as dependent from claim 2 only in which the means combining the signals produced by the first and second detectors comprises a differential amplifier.

7. A displacement sensor system according to claim 4 or claim 5 as dependent from claim 3 only in which the means combining the signals produced by the first and second detectors comprises a proportional amplifier.

8. A displacement sensor system according to any one of claims 4 to 7 in which the first and second detectors comprise photodiodes.

9. A method of sensing displacement of a target surface from a datum plane, comprising:-

generating light including first and second wavelengths or wavelength bands having a substantial spectral separation;

emitting said light from a light source which together with light-receiving means occupies a light-emitting and light-receiving surface, the light source occupying the central part of that surface and the light-receiving means occupying the peripheral part of that surface;

projecting light from the light source onto the target surface by means of a focussing lens to form a primary image of the source on the target surface and projecting light reflected from the target surface back onto said light-emitting and light-receiving surface by means of said focussing lens to form a secondary image of the source on said light-emitting and light-receiving surface said datum plane being the average focal plane for light from the light source at the first and second frequencies or frequency bands; and

producing a system output signal whose value is dependent on the relative magnitudes of the light flux received by said light-receiving means at each of the first and second wavelengths or wavelength bands, and hence also on the sense and magnitude of the displacement of the target surface from the datum plane.

10. A method according to claim 9 in which the value of the system output signal is dependent on the difference between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands respectively.

11. A method according to claim 9 in which the value of the system output signal is dependent on the ratio between the magnitudes of the light flux at each of the first and second wavelengths or wavelength bands respectively.

12. A displacement sensor system for sensing the displacement of a target surface from a datum plane, the sensor system comprising:

light-emitter means provided with a light-emitter surface for emitting light comprising at least two selected colours;

light-receiver means having a light-receiver surface for receiving light reflected from the target surface, the light-receiver surface surrounding the light-emitter surface and being co-planar therewith;

a focussing lens for projecting the light emitted by the light-emitter surface onto the target surface and for projecting light reflected from the target surface back onto the light-emitter surface and the light-receiver surface, said datum plane being the average focal plane of the focussing lens for light at the two selected colours when emitted from the light-emitter surface;

two photodetector channels;

means for splitting light received by the light-receiver means into the two selected colours and feeding each colour to a respective photodetector channel, whereby the output of each photodetector channel is a function of the magnitude of displacement of the target surface from the focal plane of the focussing lens for the colour concerned; and

means for combining the outputs of the two channels to produce a system output signal whose value is dependent on the relative magnitudes of the light fluxes in the two channels and hence also on the sense and magnitude of the displacement of the target surface from the datum plane.

13. A method for sensing the displacement of a target surface from a datum plane, in which light comprising at least two selected colours is emitted from a light-emitter surface, reflected from the target surface, and received by a light-receiver surface which surrounds the light-emitter surface and is co-planar therewith, a focussing lens being used to project the light emitted from the light-emitter surface onto the target surface and to project light reflected from the targer surface back onto the light-emitter surface and the light-receiver surface, said datum plane being the average focal plane of the focussing lens for light at the two selected colours when emitted from the light-emitter surface; wherein each of the two selected colours in the light received by the light-receiver surface is fed to a respective photodetector channel whose output is a function of the magnitude of the displacement of the target surface from the focal plane of the focussing lens for the colour concerned, the output of the channels being combined to produce a system output signal whose value is dependent on the relative magnitudes of the light fluxes in the two channels and hence also on the sense and magnitude of the displacement of the target surface from the datum plane.

14. A displacement sensor substantially as described in this specification with reference to and as illustrated by Figure 1 of the accompanying drawings.

15. A method of sensing displacement substantially as described in this specification with reference to Figure 1 of the accompanying drawings.

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